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Ionospheric Monitoring and Specification Utilizing Data from the Defense Meteorological Satellite Program

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14. ABSTRACT
Activities this year have been devoted to refinement of the ground software to accommodate the very low levels of solar activity, and to continue examination of the robustness of the procedures to recover for single event upsets. Software adaptations to accommodate the newly launched F18 sensor data and the modified operations of the F17 sensors have been accomplished. Comparisons between the data for all available DMSP satellites and from the C/NOFS satellite illustrate that the algorithms are very robust and yield highly self-consistent and high quality data.
The low levels of solar activity continue to produce a significantly contracted ionosphere that resides predominantly below the satellite altitude. Such a condition leads to the dominance of H+ is regions where O+ might be expected to be the major ion and to very low densities in the winter polar regions even when the spacecraft is in sunlight. The presence of solar illumination in the SSIES planar sensors produces photo-currents from the internal grids that may be collected. If the photo-current is larger than the ambient ion current then the sensors are rendered inoperable and a sensible signal cannot be recovered. However, when these photo-currents are comparable to the ambient ion current, a degraded performance of the sensors results and correction algorithms can be developed to recover the total ion density.

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CONTENTS

FIGURES

SSIES-3 Post-Launch Data Analysis Report

1. INTRODUCTION

Sensors that comprise both SSIES-2 and SSIES-3 instruments have been taking data from the DMSP satellites during this reporting period. Following work to improve the performance of the ground software for F17, the algorithms have been further modified this year to accommodate data from the newly launched F18 sensors.

A prolonged period of very low solar activity has extended through this reporting period, resulting in periodic investigations to verify that anomalous instrument performance is due to these conditions. In addition, various algorithmic experiments and improvements have been made to optimize the data outputs from F16, F17 and F18.

The presence of H+ as the major ion species across much of the topside ionosphere encountered by DMSP has a major detrimental impact on the performance of the ion drift meter. Since the sensor is moving at comparable velocities to the thermal speed of this species it must be excluded from the sensor in order to detect the current asymmetries produced by the more slowly moving O+ ions. Frequently the O+ number density is insufficient to correctly operate the logarithmic electrometers in the ion drift meter, thus resulting in loss of data.

The large thermal speed of H+ makes the change in the detected energy, by virtue of its bulk drift, extremely small. As a practical matter, this change in energy cannot be distinguished from extremely small variations in the potential of the sensor ground with respect to the plasma. Thus it is not possible to extract the ion drift from the RPA even when the plasma density and temperature can be recovered.

During this solar minimum period the occurrence of single-event upsets in the main electronics package has continued. The remediation steps are now well established and always result in appropriate recovery from these events. We continue to monitor the events to confirm that the characteristic behavior does not change.

Shortly after the launch of the F18 planar sensors a data anomaly affecting the output from the planar sensors and the spherical Langmuir probe was detected. At the end of this reporting period we have identified the source of the planar sensor anomaly and a mitigation procedure for much or the corrupted data. An anomaly attached to the Langmuir probe has been characterized as a separate problem and further testing is being undertaken to identify the source.

2. SSIES PROCESSING SOFTWARE

Work continued in this period on the refinement of the ground software designed to routinely process the raw data from the SSIES-2 and SSIES-3 sensor suites. The extreme solar minimum conditions have required an ongoing effort to maintain the robustness of the algorithms for both sensors and coupled with the failure of the F17 ion drift meter and possible data outages from F18, continuous evaluation of the derived geophysical parameters has been required. The algorithms are now developed to their most robust state and fail to produce valid geophysical parameters only when the ambient environment is at its most extreme.

Figure 1 shows the typical data reported by the F17 sensors during an orbit that transits the northern and southern hemispheres.

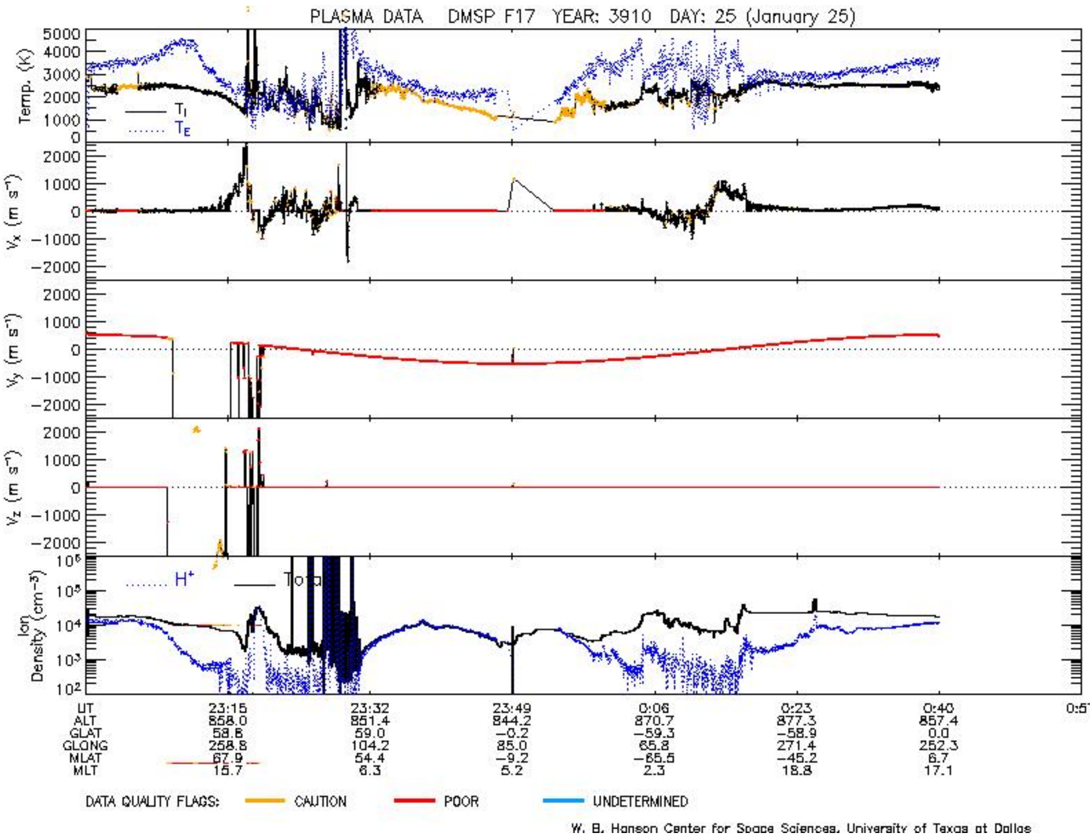

Figure 1. Data retrieved from F17 show high quality data is returned at all locations where the total density exceeds 5 x10^{3} cm^{-3}.

As has been reported previously the ion drift meter (IDM) suffered an irreparable failure in 2009 and thus no sensible data is available form this sensor. However, the retarding potential analyzer (RPA) continues to function well delivering the ram drift (Vx), the ion temperature and the ion composition. Examination of numerous data of this kind shows that in the winter hemisphere the total ion number density may fall below 5 x10^{3} cm^{-3}. If the sensor is illuminated, then an additional contribution to the current is provided by photoemission from internal grids. In this case there is insufficient signal to retard the current by another factor of 5 to retrieve temperature and composition. A signature of this data outage in the northern winter hemisphere is seen by the broad black trace in the lower panel of figure 1.

Figure 2 shows data taken during the same period from the SSIES sensor F18. In this case all the SSIES planar sensors are functional but the very low number densities in the northern winter hemisphere result in poor quality data returned from the RPA and the IDM. Further analysis of this issue is reported below, but affects only about 10% of the data gathered from the missions. The extended period of low solar activity has exacerbated this performance issue for the SSIES sensors over the period 2008-2011.

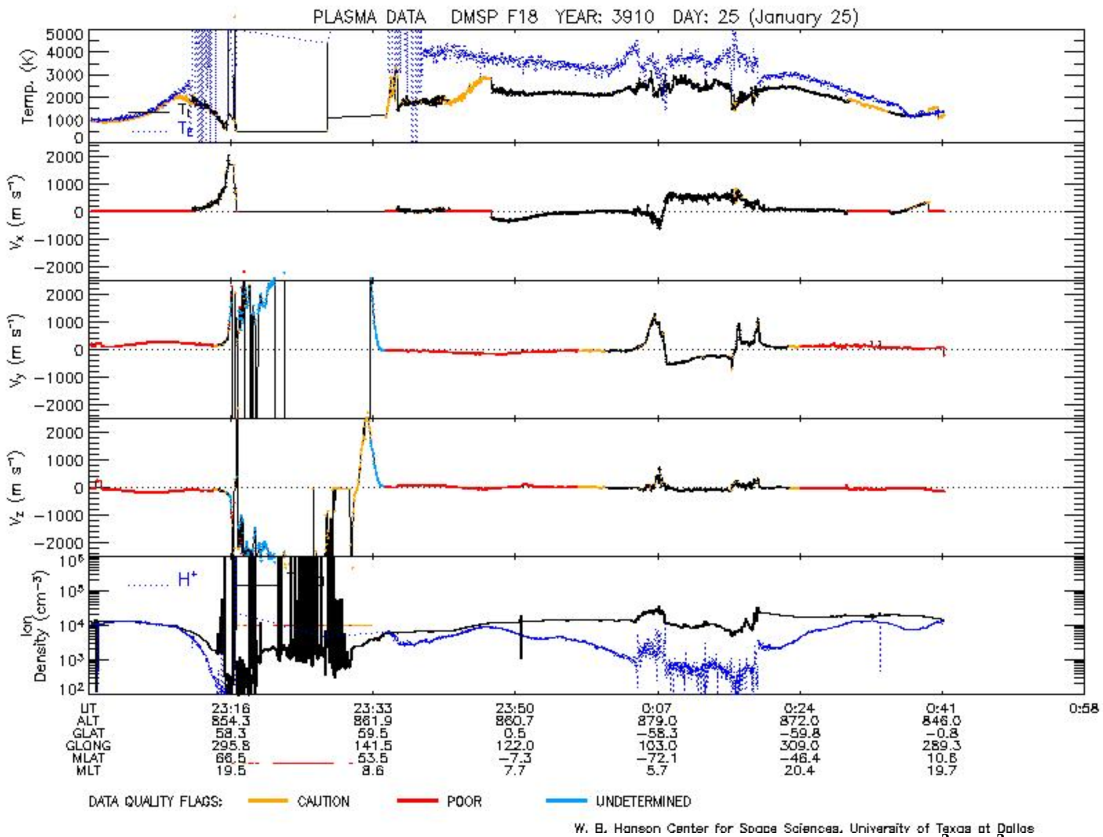

Figure 2. Data retrieved from F18 shows that for ion densities less than 5 x10^3 cm^{-3} the performanceof the all the SSIES sensors is degraded.

3. DATA VALIDATION

Opportunities for validation of the data returned from the SSIES sensors is limited by the location of the orbit in the topside ionosphere and the by the prolonged period of low solar activity that has resulted in poor signal returns from almost all space and ground based diagnostic tools. We are fortunate that during 2008-2010 the DMSP operations overlap with operations of the C/NOFS satellite. This satellite intersects the altitude of the DMSP orbit and contains instrumentation that makes essentially the same measurements. Thus an opportunity to compare the performance of each of the sensors and verify the consistency of the parameters is provided. Figure 3 shows a comparison of the total ion number density derived from the DMSP and C/NOFS satellites operating during the summer 2008.

Specifically we compare the plasma observations of density, composition, and temperature from the CINDI instrument with the same observations from four DMSP spacecraft (F13, F15, F16, and F17) during the period from 21 August to 5 September 2008 when the spacecraft intersect the same volume in the topside ionosphere through the duskside. Despite the low plasma densities at this altitude caused by the extreme solar minimum conditions during this period, the comparisons showed good agreement. For the density observations the comparisons between all spacecraft showed good agreement at all locations in the region of overlap. The temperature comparisons were good on the dayside, but were problematic on the nightside where the ion densities fell to levels outside of the operational capabilities of the RPA

analysis algorithm. Overall these comparisons have provided us with high confidence that the DMSP derived density, temperature and composition are of high quality

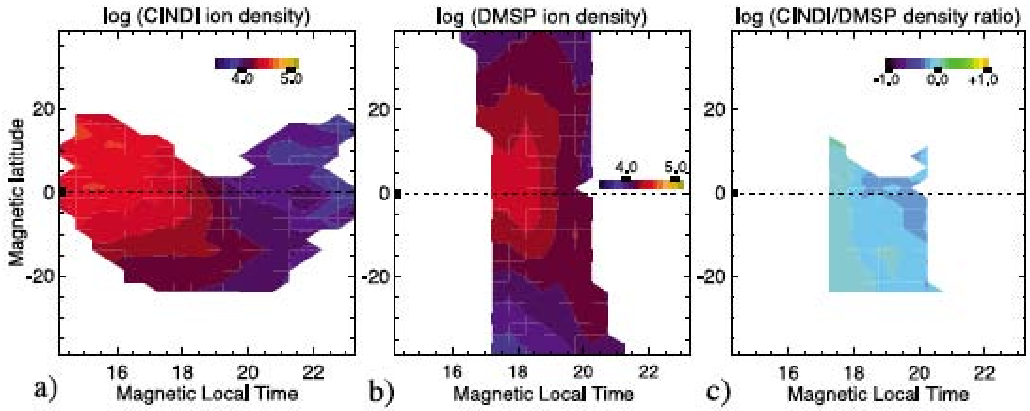

Figure 3. A comparison of total density from C/NOFS and DMSP verifies the self consistency of the these independent data sets

4. PLANAR SENSOR PHOTO-EMISSION

Shortly after the launch of the F18 satellite the SSIES planar detectors experienced degraded performance in areas of low ambient plasma density. The degraded performance manifests itself in extended periods of time in the winter hemisphere where the ion drift velocity and ion temperature, derived from the retarding potential analyzer, cannot be recovered. In addition during these same periods, the ion drift, derived from the ion drift meter is sometimes missing and the total ion density derived from the scintillation meter may require correction.

Further investigation, coupled with data gathered from SSIES operations in specific modes, indicates that the problem experienced by the retarding potential analyzer and the scintillation meter is caused by photoemission from a shield grid that is located between the sensor collector and a thermal electron suppressor grid.

This problem emerges in the presence of very low ambient ion densities that are insufficient to overcome the photo-currents from the internal grids. Analysis of the occurrence of the events and their relationship to the illumination of the sensor confirms that the severity of the data degradation is directly dependent on the sun angle and the ambient ion density.

Figure 4 provides a description of the impact of the problem on the data quality. In some cases, when the ambient ion density is very low, the signal is lost completely from the sensors. In this case the data are not recoverable. However, in other cases the data are recoverable from a measurement of the photo-current that can be added to the observed ion current. The full details of the data outage from this source are reported in a different document that will be finalized and published in the coming year.

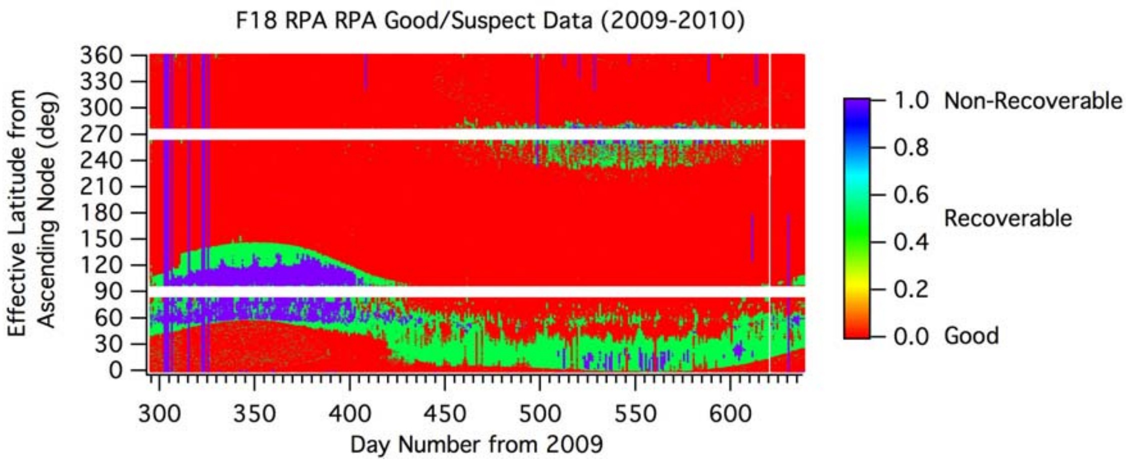

Figure 4. For a period of 1 year each data location is flagged as unaffected (red) recoverable (green) or irrecoverable (blue)

5. MISCELLANEOUS ACTIVITIES

During this period we have continued to populate the DMSP data website to enable scientists at UTD and AFRL to readily examine the SSIES data. For the present solar minimum conditions, where the analysis procedures have been tested to their maximum capability, it has been particularly helpful. UTD has also continued to provide support services to AFRL as requested during this period. These include verification of single event upsets and responses to other performance and data analysis anomalies.

6. SCIENTISTS AND ENGINEERS CONTRIBUTING TO THIS RESEARCH

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R. A. Power	Project Supervisor